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MULTI-BEAM SCANNING DEVICE, MULTI-BEAM SCANNING METHOD, LIGHT SOURCE DEVICE, AND IMAGE FORMING APPARATUS

Japanese Unexamined Patent No. 2001-194605

Laid-open on: July 19, 2001

Application No. 2000-4624

Filed on: January 13, 2000

Inventor: Koji SAKAI, Naoki MIYATAKE

Applicant: Ricoh Co., Ltd.

Patent Attorney: Toru KAYAMA

SPECIFICATION

[TITLE OF THE INVENTION] Multi-beam scanning device, multi-beam scanning method, light source device, and image forming apparatus

[Abstract]

[Object] To detect a plurality of deflected light beams individually by synchronous light detecting means in multi-beam scanning.

[Solving means] A multi-beam scanning device has synchronous light detecting means 22 and 24 that detect the deflected light beam traveling to the scanning area of a to-be-scanned surface 20, a light source device 10 for emitting a plurality of light

beams has semiconductor lasers 1a-1c and N coupling lenses 2a-2c having a 1:1 correspondence relationship to lasers, and each of the coupling lenses has the same structure, the optical axes of the lenses being made parallel to each other with respect to the main scanning direction. In the light receiving surface position of the synchronous light detecting means, when two arbitrary deflected light beams contiguous to each other are represented as Bi and Bi+1(i=1 to N-1) and when the deviation amounts in the main scanning direction from the optical axes of the coupling lenses of semiconductor laser light-emitting parts that emit the beams Bi and Bi+1 are represented as ζi and ζi+1, the deviation amounts: ζi and ζi+1 satisfy the relation: $\Delta \leq M\ (\mathrm{main}) \cdot |\zeta i - \zeta i+1|$ with respect to the lateral magnification: M (main) in the main scanning direction of the optical system disposed between each semiconductor laser and the light receiving surface position and with respect to the resolution :Δ of the synchronous light detecting means.

[WHAT IS CLAIMED IS;]

[Claim 1] A multi-beam scanning device for condensing a plurality of deflected light beams that are emitted from a light source device and are deflected toward a to-be-scanned surface through a scanning image formation optical system, for forming

a plurality of light spots that are mutually separated in a sub-scanning direction on the to-be-scanned surface, and for scanning a plurality of lines simultaneously by these light spots wherein,

the multi-beam scanning device has synchronous light detecting means for detecting the deflected light beam traveling to a scanning area of the to-be-scanned surface in order to synchronize the starting of scanning operations using the deflected light beams,

the light source device that emits a plurality of light beams has at least N (≥2) semiconductor lasers and at least N coupling lenses that have a 1:1 correspondence relationship with respect to each of the semiconductor lasers,

the N coupling lenses are identical in structure with each other, the optical axes of the lenses being made parallel to each other with respect to a main scanning direction, and

when two arbitrary deflected light beams contiguous to each other are represented as Bi and Bi+1(i=1 to N-1) in a light receiving surface position of the synchronous light detecting means and when deviation amounts in the main scanning direction from the optical axes of corresponding coupling lenses of semiconductor laser light-emitting parts that emit the beams Bi and Bi+1 are represented as ζi and ζi+1,

the deviation amounts: ζi and $\zeta i+1$ are set to satisfy relation: $\Delta \leq M$ (main) $\cdot |\zeta i - \zeta i+1|$ with respect to a lateral magnification: M (main) in the main scanning direction of an optical system disposed between each semiconductor laser and the light receiving surface position and with respect to a resolution: Δ of the synchronous light detecting means, thereby making it possible to detect each of the deflected light beams individually by the synchronous light detecting means.

[Claim 2] A multi-beam scanning device for condensing a plurality of deflected light beams that are emitted from a light source device and are simultaneously deflected toward a to-be-scanned surface through a scanning image formation optical system, for forming a plurality of light spots that are mutually separated in a sub-scanning direction on the to-be-scanned surface, and for scanning a plurality of lines simultaneously by these light spots wherein:

the multi-beam scanning device has synchronous light detecting means for detecting the deflected light beam traveling to a scanning area of the to-be-scanned surface in order to synchronize the starting of scanning operations using the deflected light beams, and

the light source device that emits a plurality of light beams has

a first light source part having n (≥2) semiconductor lasers, n coupling lenses that have a 1:1 correspondence relationship with respect to each of the semiconductor lasers, and a holding body that holds together the n semiconductor lasers and the n coupling lenses while making the optical axes of the n coupling lenses parallel to each other with respect to a main scanning direction so as to be maintained in a predetermined positional relationship,

a second light source part having m (≥2) semiconductor lasers, m coupling lenses that have a 1:1 correspondence relationship with respect to each of the semiconductor lasers, and a holding body that holds together the m semiconductor lasers and the m coupling lenses while making the optical axes of the m coupling lenses parallel to each other with respect to the main scanning direction so as to be maintained in a predetermined positional relationship, and

beam combining means for combining the n light beams emitted from the first light source part and the m light beams emitted from the second light source part into light beams in close vicinity to each other, and

a deviation amount: ζi (i=1 to n) in the main scanning direction from the optical axis of a corresponding coupling lens of an arbitrary semiconductor laser light-emitting part

in the first light source part,

a deviation amount: ζk(k=1 to m) in the main scanning direction from the optical axis of a corresponding coupling lens of an arbitrary semiconductor laser light-emitting part in the second light source part, and

a positional relationship among the first and second light source parts and the beam combining means are set so that

deflected light beams contiguous to each other are separated in the main scanning direction by a distance exceeding a resolution: Δ of the synchronous light detecting means in a light receiving surface position of the synchronous light detecting means, thereby making it possible to detect each of the deflected light beams individually by the synchronous light detecting means.

[Claim 3] A multi-beam scanning device as set forth in Claim 2, wherein n=m, and the first light source part and the second light source part have the same structure.

[Claim 4] A multi-beam scanning device as set forth in Claim 3, wherein each of the semiconductor lasers in the first and second light source parts of the light source device is pressed and fixed into a corresponding holding hole of the holding body, and each of the coupling lenses is fixed to a corresponding holding body with an adhesive resin, and an optical-axis

position with respect to a corresponding light-emitting part of the semiconductor laser is adjusted by the adhesive resin.

[Claim 5] A multi-beam scanning device as set forth in Claim 4, wherein n=m=2.

[Claim 6] A multi-beam scanning device for condensing a plurality of deflected light beams that are emitted from a light source device and are deflected toward a to-be-scanned surface through a scanning image formation optical system, for forming a plurality of light spots that are mutually separated in a sub-scanning direction on the to-be-scanned surface, and for scanning a plurality of lines simultaneously by these light spots wherein:

the multi-beam scanning device has synchronous light detecting means for detecting the deflected light beam traveling to a scanning area of the to-be-scanned surface in order to synchronize the starting of scanning operations using the deflected light beams,

the light source device that emits a plurality of light beams has at least N (≥2) semiconductor lasers and at least N coupling lenses that have a 1:1 correspondence relationship with respect to each of the semiconductor lasers,

the N coupling lenses are identical in structure with each other, the optical axes of the lenses being made nonparallel

to each other with respect to a main scanning direction, and,

when two arbitrary deflected light beams contiguous to each other are represented as Bi and Bi+1(i=1 to N-1) in a light receiving surface position of the synchronous light detecting means,

an angle: φi in the main scanning direction between the optical axes of the coupling lenses corresponding to the semiconductor lasers that emit these beams Bi and Bi+1 is set so that a distance in the main scanning direction between the beams Bi and Bi+1 exceeds a resolution: Δ of the synchronous light detecting means, thereby making it possible to detect each of the deflected light beams individually by the synchronous light detecting means.

[Claim 7] A multi-beam scanning device for condensing a plurality of deflected light beams that are emitted from a light source device and are simultaneously deflected toward a to-be-scanned surface through a scanning image formation optical system, for forming a plurality of light spots that are mutually separated in a sub-scanning direction on the to-be-scanned surface, and for scanning a plurality of lines simultaneously by these light spots wherein:

the multi-beam scanning device has synchronous light detecting means for detecting the deflected light beam

traveling to a scanning area of the to-be-scanned surface in order to synchronize the starting of scanning operations using the deflected light beams, and

the light source device that emits a plurality of light beams has

a first light source part having n (≥2) semiconductor lasers, n coupling lenses that have a 1:1 correspondence relationship with respect to each of the semiconductor lasers, and a holding body that holds together the n semiconductor lasers and the n coupling lenses so that the optical axes of the n coupling lenses mutually make a predetermined angle in a main scanning direction while being maintained in a predetermined positional relationship,

a second light source part having m (≥2) semiconductor lasers, m coupling lenses that have a 1:1 correspondence relationship with respect to each of the semiconductor lasers, and a holding body that holds together the m semiconductor lasers and the m coupling lenses so that the optical axes of the m coupling lenses mutually make a predetermined angle in a main scanning direction while being maintained in a predetermined positional relationship, and

beam combining means for combining the n light beams emitted from the first light source part and the m light beams emitted

from the second light source part into light beams in close vicinity to each other, and

an optical-axis direction of each of the coupling lenses in the first and second light source parts and a mutual positional relationship among the first and second light source parts and the beam combining means are set so that deflected light beams contiguous to each other are mutually separated in the main scanning direction by a distance exceeding a resolution : Δ of the synchronous light detecting means, thereby making it possible to individually detect the deflected light beams by the synchronous light detecting means.

[Claim 8] A multi-beam scanning device as set forth in Claim 7, wherein n=m, and the first light source part and the second light source part have the same structure.

[Claim 9] A multi-beam scanning device as set forth in Claim 8, wherein each semiconductor laser light-emitting part in the light source device is disposed on the optical axis of a corresponding coupling lens.

[Claim 10] A multi-beam scanning device as set forth in Claim 8, wherein n=m=2.

[Claim 11] A multi-beam scanning device as set forth in Claim 6, wherein at least P (2≤P≤N) light emitting parts of the N (≥2) semiconductor lasers deviate from the optical axis of a

corresponding coupling lens in the main scanning direction.

[Claim 12] A multi-beam scanning device as set forth in Claim 7, wherein at least P ($2 \leq P \leq n+m$) light emitting parts of n+m semiconductor lasers deviate from the optical axis of a corresponding coupling lens in the main scanning direction.

[Claim 13] A multi-beam scanning device as set forth in Claim 12, wherein n=m, and the first light source part and the second light source part have the same structure.

[Claim 14] A multi-beam scanning device as set forth in Claim 13, wherein n=m=2.

[Claim 15] A multi-beam scanning device as set forth in any one of Claims 1 to 14, wherein the structure is formed so that a plurality of light beams emitted from the light source device are simultaneously deflected by the same deflection reflective surface of an optical deflector, and the light source device is structured so that the plurality of light beams intersect in the vicinity of the deflection reflective surface in the main scanning direction.

[Claim 16] A multi-beam scanning device as set forth in any one of Claims 1 to 15, wherein:

the structure is formed so that a plurality of light beams emitted from the light source device are simultaneously deflected by the same deflection reflective surface of the

optical deflector,

there is provided a line image formation optical system that forms the plurality of light beams emitted from the light source device between the light source device and the optical deflector as line images long in the main scanning direction that are mutually separated in the sub-scanning direction in the vicinity of the deflection reflective surface, and the scanning image formation optical system is anamorphic so as to establish a geometrical-optical conjugate relationship in the sub-scanning direction between the deflection reflective surface position and the to-be-scanned surface position.

[Claim 17] A light source device used for a multi-beam scanning device, having the structure set forth in any one of Claims 1 to 16.

[Claim 18] A multi-beam scanning method for condensing a plurality of deflected light beams that are emitted from a light source device and are deflected toward a to-be-scanned surface through a scanning image formation optical system, for forming a plurality of light spots that are mutually separated in the sub-scanning direction on the to-be-scanned surface, and for scanning a plurality of lines simultaneously by these light spots, wherein the method is performed by the use of the multi-beam scanning device as set forth in any one of Claims

1 to 15.

[Claim 19] A multi-beam scanning method for condensing a plurality of deflected light beams that are emitted from a light source device and are deflected toward a to-be-scanned surface through a scanning image formation optical system, for forming a plurality of light spots that are mutually separated in the sub-scanning direction on the to-be-scanned surface, and for scanning a plurality of lines simultaneously by these light spots, wherein the method is performed by the use of the multi-beam scanning device as set forth in Claim 16.

[Claim 20] An image forming apparatus for forming a latent image on a latent image carrier by optical scanning and obtaining a desired recorded image by visualizing the latent image, wherein the multi-beam scanning device as set forth in any one of Claims 1 to 15 is used as an optical scanning device for subjecting the latent image carrier to optical scanning.

[Claim 21] An image forming apparatus for forming a latent image on a latent image carrier by optical scanning and obtaining a desired recorded image by visualizing the latent image, the multi-beam scanning device as set forth in Claim 16 is used as an optical scanning device for subjecting the latent image carrier to optical scanning.

[Claim 22] An image forming apparatus as set forth in Claim

20 or 21, wherein the latent image carrier is a photoconductive photo conductor, an electrostatic latent image is formed by uniform electrification thereof and by optical scanning, and a formed electrostatic latent image is visualized as a toner image.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Field of the Invention] This invention relates to a multi-beam scanning device, a multi-beam scanning method, a light source device, and an image forming apparatus.

[0002]

[Prior art] Conventionally, various proposals have been made concerning a multi-beam scanning device for condensing a plurality of deflected light beams that are emitted from a light source device and are deflected toward a to-be-scanned surface through a shared scanning image formation optical system, for forming a plurality of light spots that are mutually separated in the sub-scanning direction on the to-be-scanned surface, and for scanning a plurality of lines simultaneously by these light spots, and, from the viewpoint of increased efficiency in performing the optical scanning, its realization is currently targeted. A plurality of light beams are needed to perform multi-beam scanning, and light emitting parts the

number of which corresponds to the number of the light beams are needed for the light source device. A semiconductor laser array can be used, or a plurality of independent semiconductor lasers can be used as this type of light emitting part whose number to be disposed is plural. In the semiconductor laser array, since light emitting parts that are arrayed are in close vicinity to each other, there exists the problem of so-called "cross talk" in which the emissive powers of the adjoining light emitting parts influence each other, and therefore it is difficult to control the quantity of light with high accuracy. If a plurality of independent semiconductor lasers are used as light emitting parts, the problem of cross talk does not occur, and the quantity of light of each of the semiconductor lasers can be controlled with high accuracy. In the case of multi-beam scanning, a plurality of lines of a to-be-scanned surface are scanned simultaneously, and therefore it is necessary to individually arrange the start positions of scanning of the deflected light beams. In order to carry this out, a possible method is to arrange light spots formed by the plurality of deflected light beams "in a single row in the sub-scanning direction," to detect an arbitrary one of the light spots by the use of a "synchronous light detecting means for starting a scanning operation," and to subject all of the

light spots to the same synchronous control.

[0003] If the plurality of light spots are separated in the main scanning direction, there is a method of pre-determining the "separation amount in the main scanning direction between adjoining light spots" as a design condition, of detecting a light spot that starts scanning at first by the synchronous light detecting means, of synchronizing the start of scanning of the "light spot that starts scanning at first" based on a detection signal, and thereafter of sequentially generating a synchronizing signal of the start of scanning of a subsequent light spot according to a delay time corresponding to the separation amount in the main scanning direction between the subsequent light spot and the "light spot that starts scanning initially." If the "plurality of independent semiconductor lasers" are used as the light emitting parts of the light source device, a possible problem resides in the fact that the mechanical accuracy of the optical system deteriorates with the lapse of time in response to mechanical vibrations and environmental changes, and, when the mutual positional relationship between the light spots changes with the lapse of time, a "deviation" occurs with the lapse of time in the start position of scanning between the light spots so as to deteriorate an image to be written in the above-mentioned

"method of synchronizing the starting of scanning of the other light spots on the basis of one of the light spots." Therefore, in order to avoid this problem, it is recommended to separate the plurality of light spots in the main scanning direction, to detect the respective light spots individually, and to individually synchronize the starting of scanning with respect to the plurality of light spots, like the invention disclosed in Japanese Unexamined Patent Application Publication No. H8-179229.

[0004]

[Themes to be Solved by the Invention] This invention aims to, when a plurality of independent semiconductor lasers are used as light emitting parts of a light source device in multi-beam scanning, realize a new multi-beam scanning device and multi-beam scanning method, a new light source device used for the multi-beam scanning device, and a new image forming apparatus using the multi-beam scanning device, each capable of detecting a plurality of deflected light beams individually by synchronous light detecting means.

[0005]

[Means for Solving Themes] The multi-beam scanning device of this invention is basically a "multi-beam scanning device for condensing a plurality of deflected light beams that are

emitted from a light source device and are deflected toward a to-be-scanned surface through a scanning image formation optical system, for forming a plurality of light spots that are mutually separated in a sub-scanning direction on the to-be-scanned surface, and for scanning a plurality of lines simultaneously by these light spots," and, in order to synchronize the start of scanning by each deflected light beam, has "synchronous light detecting means for detecting the deflected light beam traveling to a scanning area of the to-be-scanned surface." The "scanning image formation optical system" to condense a plurality of deflected light beams toward the to-be-scanned surface and to form light spots can be formed of a single lens or two or more lenses, or can have a structure including one or more lenses and "one or more mirrors having an image formation function." As mentioned above, the synchronous light detecting means detects deflected light beams traveling to the scanning area of the to-be-scanned surface. Therefore, the synchronous light detecting means has "light receiving means" by which a deflected light beam is received, and a light-reception signal is generated. A light receiving surface of the light receiving means is disposed, for example, at a "position that is equivalent to the to-be-scanned surface and at which a light beam traveling to the

scanning area can be received." The position equivalent to the to-be-scanned surface is a "a position at which a light beam received on the light receiving surface is substantially condensed on the light receiving surface at least in the main scanning direction."

[0006] For example, if the light receiving surface is disposed at a position equivalent to the to-be-scanned surface so that a "light beam that has passed through the scanning image formation optical system" is made incident upon the light receiving surface, a light spot that is the same as the one on the to-be-scanned surface is formed on the light receiving surface. The scanning image formation optical system often includes "a long toroidal lens or cylindrical lens that has substantially no power in the main scanning direction in order to correct the surface inclination and the field curvature of a rotational polygon mirror" at a position closest to the to-be-scanned surface. In this case, the long toroidal lens or cylindrical lens does not have substantial power in the main scanning direction, and therefore a light spot is formed by a "part excluding the toroidal lens or cylindrical lens" of the scanning image formation optical system concerning the main scanning direction. In this case, if the light receiving surface of the synchronous light detecting means is placed at

a position equivalent to the to-be-scanned surface, and if a "deflected light beam that has passed through a part excluding the toroidal lens or cylindrical lens" of the scanning image formation optical system is received by the light receiving surface, the spot to be formed on the light receiving surface will be an "elliptical spot that has a width equal to that of a light spot in the main scanning direction and that is long in the sub-scanning direction." However, this spot is sufficient to be used as synchronous light. In this case, it is also possible to dispose the cylindrical lens in the vicinity of the light receiving surface so that a light beam can be condensed on the light receiving surface also in the sub-scanning direction. Of course, the structure can be formed so that the light beam deflected toward the scanning area is "condensed at least in the main scanning direction" on the light receiving surface of the light receiving means of the synchronous light detecting means by a dedicated optical system without using the scanning image formation optical system.

[0007] Now, the multi-beam scanning device as set forth in Claim 1 has the following features. That is, the light source device that emits a plurality of light beams has at least N (≥2) semiconductor lasers and at least N coupling lenses that have a 1:1 correspondence relationship with respect to each of the

semiconductor lasers. The N coupling lenses are identical in structure with each other, and the optical axes of the lenses are made parallel to each other with respect to the main scanning direction. In other words, when these are seen from the sub-scanning direction, the optical axes of the N coupling lenses are parallel to each other. Two arbitrary deflected light beams contiguous to each other are represented as Bi and Bi+1(i=1 to N-1) in the light receiving surface position of the synchronous light detecting means. The semiconductor laser light-emitting parts that emit these beams Bi and Bi+1 are deviated in the main scanning direction from the optical axes of corresponding coupling lenses by deviation amounts of ζi and $\zeta i+1$. The deviation amounts: ζi and $\zeta i+1$ are set to satisfy relation: $\Delta \leq M$ (main) $\cdot |\zeta i - \zeta i+1|$ with respect to a resolution: Δ of the synchronous light detecting means wherein M (main) is a lateral magnification in the main scanning direction of an optical system disposed between each semiconductor laser and the light receiving surface position, thereby making it possible to detect each of the deflected light beams individually by the synchronous light detecting means. It is permissible that one of the deviation amounts: ζi and $\zeta i+1$ (i=1 to N-1) is equal to "0." The "resolution: Δ of the synchronous detecting means" denotes the "limit of a separation amount in

the main scanning direction on the light receiving surface" that is required of the two deflected light beams, because the synchronous light detecting means can "separate" the two deflected light beams contiguous to each other in the main scanning direction and can "detect them as distinct light beams." This resolution is approximately 0.5mm in a photosensor that is a typical light receiving means.

[0008] The multi-beam scanning device as set forth in Claim 2 has the following features. That is, the light source device that emits a plurality of light beams has a first light source part, a second light source part, and a beam combining means. The "first light source part" has n (≥2) semiconductor lasers, n coupling lenses that have a 1:1 correspondence relationship with respect to each of the semiconductor lasers, and a holding body that holds together the n semiconductor lasers and the n coupling lenses while making the optical axes of the n coupling lenses parallel to each other with respect to a main scanning direction so as to be maintained in a predetermined positional relationship. The "second light source part" has m (≥2) semiconductor lasers, m coupling lenses that have a 1:1 correspondence relationship with respect to each of the semiconductor lasers, and a holding body that holds together the m semiconductor lasers and the m coupling lenses while

making the optical axes of the m coupling lenses parallel to each other with respect to the main scanning direction so as to be maintained in a predetermined positional relationship. The "beam combining means" is a means for combining the n light beams emitted from the first light source part and the m light beams emitted from the second light source part into light beams that are in close vicinity to each other. A deviation amount: ζi (i=1 to n) in the main scanning direction from the optical axis of a corresponding coupling lens of an arbitrary semiconductor laser light-emitting part in the first light source part, a deviation amount: ζk(k=1 to m) in the main scanning direction from the optical axis of a corresponding coupling lens of an arbitrary semiconductor laser light-emitting part in the second light source part, and a positional relationship among the first and second light source parts and the beam combining means are set so that "deflected light beams contiguous to each other are separated in the main scanning direction by a distance exceeding the resolution: Δ in a light receiving surface position of the synchronous light detecting means," thereby making it possible to detect each of the deflected light beams individually by the synchronous light detecting means.

[0009] In the multi-beam scanning device as set forth in Claim

2, it is possible that n=m and that the first light source part and the second light source part have the same structure (Claim 3), and, in this case, "each of the semiconductor lasers in the first and second light source parts of the light source device is pressed and fixed into a corresponding holding hole of the holding body, and each of the coupling lenses is fixed to a corresponding holding body with an adhesive resin, and an optical-axis position with respect to a corresponding light-emitting part of the semiconductor laser is adjusted by the adhesive resin" (Claim 4). Additionally, in this case, it is possible that n=m=2 (Claim 5). For example, an "ultraviolet-cured resin" can be used as the "adhesive resin." If an adhesive resin is used to fix the coupling lens to the holding body and if the optical-axis position with respect to the semiconductor laser light-emitting part is adjusted by (the amount or the like of) the adhesive resin like the invention as set forth in Claim 4, the adhesive resin makes a change in volume caused by "a temperature change or a humidity change," and therefore a relative relationship between the light emitting part and the optical axis of the coupling lens will change by an environmental change. In this case, if only one light spot is detected by the synchronous light detecting means and if the synchronization of the start position of scanning

of other light spots is fixedly controlled based on this light spot, there is a fear that the above-mentioned "time-dependent deviation in the start position of scanning between light spots will occur, but, since the light beams are individually detected by the synchronous light detecting means in this invention, a proper timing of the start of scanning can be given to each of the light beams.

[0010] The multi-beam scanning device as set forth in Claim 6 has the following features. That is, the light source device that emits a plurality of light beams has at least N (≥2) semiconductor lasers and at least N coupling lenses that have a 1:1 correspondence relationship with respect to each of the semiconductor lasers. The N coupling lenses are identical in structure with each other, and the optical axes of the lenses are made nonparallel to each other with respect to a main scanning direction. When two arbitrary deflected light beams contiguous to each other are represented as Bi and Bi+1(i=1 to N-1) in a light receiving surface position of the synchronous light detecting means, an angle: φi of the optical axis of the coupling lens corresponding to the semiconductor laser that emits these beams Bi and Bi+1 with respect to the main scanning direction is set so that a distance between the beams Bi and Bi+1 in the main scanning direction exceeds a resolution: Δ

of the synchronous light detecting means. Therefore, each of the deflected light beams can be individually detected by the synchronous light detecting means. The multi-beam scanning device as set forth in Claim 7 has the following features. That is, the light source device that emits a plurality of light beams has a first light source part, a second light source part, and a beam combining means. The "first light source part" has n (≥2) semiconductor lasers, n coupling lenses that have a 1:1 correspondence relationship with respect to each of the semiconductor lasers, and a holding body that holds together the n semiconductor lasers and the n coupling lenses so that the optical axes of the n coupling lenses mutually make a predetermined angle in a main scanning direction while being maintained in a predetermined positional relationship.

[0011] The "second light source part" has m (≥2) semiconductor lasers, m coupling lenses that have a 1:1 correspondence relationship with respect to each of the semiconductor lasers, and a holding body that holds together the m semiconductor lasers and the m coupling lenses so that the optical axes of the m coupling lenses mutually make a predetermined angle in a main scanning direction while being maintained in a predetermined positional relationship. The "beam combining means" is a means for combining the n light beams emitted from

the first light source part and the m light beams emitted from the second light source part into light beams that are in close vicinity to each other. An optical-axis direction of each of the coupling lenses in the first and second light source parts and a mutual positional relationship among the first and second light source parts and the beam combining means are set so that deflected light beams contiguous to each other are mutually separated in the main scanning direction by a distance exceeding a resolution : Δ of the synchronous light detecting means. Therefore, each of the deflected light beams can be individually detected by the synchronous light detecting means. In this multi-beam scanning device as set forth in Claim 7, it is possible that n=m and that the first light source part and the second light source part have the same structure (Claim 8). In the multi-beam scanning device as set forth in Claim 8, each semiconductor laser light-emitting part in the light source device can be disposed on the optical axis of a corresponding coupling lens (Claim 9). Additionally, in the multi-beam scanning device as set forth in Claim 8, it is possible that n=m=2 (Claim 10). In the multi-beam scanning device as set forth in Claim 6, at least P (2≤P≤N) light emitting parts of the N (≥2) semiconductor lasers can be disposed so as to deviate from the optical axis of a corresponding coupling

lens in the main scanning direction (Claim 11). In the multi-beam scanning device as set forth in Claim 7, at least P ($2 \leq P \leq n+m$) light emitting parts of n+m semiconductor lasers can be disposed so as to deviate from the optical axis of a corresponding coupling lens in the main scanning direction (Claim 12). In this case, it is possible that n=m and that the first light source part and the second light source part have the same structure (Claim 13). In the multi-beam scanning device as set forth in Claim 13, it is possible that n=m=2 (Claim 14).

[0012] The multi-beam scanning device as set forth in Claim 15 is characterized in that, in the multi-beam scanning device as set forth in any one of Claims 1 to 14, the structure is formed so that a plurality of light beams emitted from the light source device are simultaneously deflected by the same deflection reflective surface of an optical deflector, and the light source device is structured so that the plurality of light beams intersect in the vicinity of the deflection reflective surface in the main scanning direction. The multi-beam scanning device as set forth in Claim 16 is characterized in that, in the multi-beam scanning device as set forth in any one of Claims 1 to 15, the structure is formed so that a plurality of light beams emitted from the light source device are simultaneously

deflected by the same deflection reflective surface of the optical deflector, there is provided a line image formation optical system that forms the plurality of light beams emitted from the light source device between the light source device and the optical deflector as "line images long in the main scanning direction" that are mutually separated in the sub-scanning direction in the vicinity of the deflection reflective surface, and the scanning image formation optical system is anamorphic so as to establish a geometrical-optical conjugate relationship in the sub-scanning direction between the deflection reflective surface position and the to-be-scanned surface position. The surface inclination of the deflection reflective surface can be corrected by structuring the multi-beam scanning device in this way. The "light source device" of this invention is characterized by being a light source device used for the multi-beam scanning device and is characterized by having the structure set forth in any one of Claims 1 to 16 (Claim 17). The multi-beam scanning method of this invention is a multi-beam scanning method for condensing a plurality of deflected light beams that are emitted from a light source device and are deflected toward a to-be-scanned surface through a scanning image formation optical system, for forming a plurality of light spots that are mutually separated

in the sub-scanning direction on the to-be-scanned surface, and for scanning a plurality of lines simultaneously by these light spots.

[0013] The multi-beam scanning method as set forth in Claim 18 is characterized by being performed by the use of the multi-beam scanning device as set forth in any one of Claims 1 to 15. The multi-beam scanning method as set forth in Claim 19 is characterized by being performed by the use of the multi-beam scanning device as set forth in Claim 16. The image forming apparatus of this invention is an " image forming apparatus for forming a latent image on a latent image carrier by optical scanning and obtaining a desired recorded image by visualizing the latent image." The image forming apparatus as set forth in Claim 20 is characterized by using the multi-beam scanning device as set forth in any one of Claims 1 to 15 as an optical scanning device for subjecting the latent image carrier to optical scanning, and the image forming apparatus as set forth in Claim 21 is characterized by using the multi-beam scanning device as set forth in Claim 16 as an optical scanning device for subjecting the latent image carrier to optical scanning. In the image forming apparatus as set forth in Claim 20 or 21, the structure can be formed so that the latent image carrier is a photoconductive photo conductor, and an

electrostatic latent image is formed by uniform electrification thereof and by optical scanning, and a formed electrostatic latent image is visualized as a toner image (Claim 22). The toner image is fixed to a sheet-like recording medium (transfer paper or plastic sheet for an overhead projector). In the image forming apparatus as set forth in Claim 20 or 21, for example, a silver-halide-photography film can be used as a photosensitive medium. In this case, a latent image formed through optical scanning by the multi-beam scanning device can be visualized by a developing technique of an ordinary silver-halide-photography process. This type of image forming apparatus can be carried out, for example, as a "photoengraving device." Additionally, the image forming apparatus as set forth in Claim 22 can be carried out concretely as a laser beam printer, a laser plotter, a digital copying machine, a facsimile machine, etc. As described above, in the multi-beam scanning device, the plurality of light spots must be mutually separated in the sub-scanning direction on the to-be-scanned surface. Various methods can be employed to separate the plurality of light spots in the sub-scanning direction on the to-be-scanned surface. If the light source device has a plurality of semiconductor lasers and a plurality of coupling lenses that have a 1:1 correspondence relationship

with respect to these semiconductor lasers as in each multi-beam scanning device described above, the light spots may be separated in the sub-scanning direction, for example, by deviating the light-emitting part of a corresponding semiconductor laser in the sub-scanning direction with respect to the optical axis of a coupling lens and by adjusting a "deviation amount in the sub-scanning direction of the light emitting part with respect to the coupling-lens optical axis" for each pair of the semiconductor laser and the coupling lens, or, alternatively, the light spots can be mutually separated in the sub-scanning direction by allowing the optical axes of the coupling lenses to mutually make a slight angle in the sub-scanning direction and by adjusting the angle of each optical axis with the sub-scanning direction, or, alternatively, the light spots may be separated mutually in the sub-scanning direction by adjusting the direction of the optical axis and a "deviation amount in the sub-scanning direction from the optical axis of the light emitting part."

[0014] The coupling operation of the coupling lens described above may be the operation of making the divergent light beam from the light emitting part of a corresponding semiconductor laser into parallel beams or may be the operation of making them into divergent or convergent light beams.

[0015]

[Preferred Embodiments] In Fig. 1(a), three light beams are emitted from a light source device designated by reference numeral 10 (in order to avoid making the figure complicated, only one of the light beams emitted from the light source device 10 is drawn). The emitted light beams (which are substantial collimated beams) are made incident on a cylindrical lens 12 used as a line image formation optical system. The cylindrical lens 12 has positive power only in the sub-scanning direction, and focuses the three light beams impinging thereon only in the sub-scanning direction, and forms them as line images long in the main scanning direction in the vicinity of the deflection reflective surface of a rotational polygon mirror 14 used as an optical deflector. The line image is formed for each light beam, and the line images are mutually separated in the sub-scanning direction. When the rotational polygon mirror 14 is rotated at uniform speed in the direction of an arrow by a motor not shown, the three light beams that have been reflected on the deflection reflective surface are deflected at a uniform angular velocity in the form of deflected light beams. Each of the deflected light beams is made incident on an fθ lens 16 used as a scanning image formation optical system while being deflected, and, when the beams pass through the

fθ lens 16, the beams are reflected by a return mirror 18, which is a long plane mirror, so that the optical paths thereof are bent, and the beams are condensed on the circumferential surface of a photo conductor 20, which forms the substance of a to-be-scanned surface, as light spots by the operation of the fθ lens 16. The three light spots formed on the to-be-scanned surface are mutually separated in the sub-scanning direction, and, as shown in the figure, three lines on the to-be-scanned surface are simultaneously scanned at a time. A plane mirror 22 is disposed in the vicinity of a "scanning-start side end" in the longitudinal direction of the return mirror 18. A region in which the plane mirror 22 is disposed is outside an effective deflection area necessary for the deflected light beams to scan the effective scanning area of the to-be-scanned surface. The deflected light beams reflected by the plane mirror 22 are made incident on a photosensor 24 that is a light receiving means for synchronous photodetection. That is, each of the deflected light beams is first made incident on the plane mirror 22 while being deflected on the way to the scanning area of the to-be-scanned surface, is then reflected, is then made incident on the photosensor 24, and is received. The light receiving surface of the photosensor 24 is disposed at a "position optically equivalent

to the to-be-scanned surface." Since each of the deflected light beams incident on the plane mirror 22 has received the optical operation of the fθ lens 16, each of the deflected light beams is condensed on the light receiving surface of the photosensor 24 as the same light spot as in the to-be-scanned surface. In this embodiment, the plane mirror 22 and the photosensor 24 constitute the "synchronous light detecting means." The light receiving area of the light receiving surface of the photosensor 24 has such a size so as to have a resolution: Δ(0.5mm, for example) in the main scanning direction.

[0016] Fig. 1(b) shows a main part of the light source device 10 of Fig. 1(a) in the manner of an explanatory drawing. The main part of the light source device 10 has three semiconductor lasers 1a and 1b, and 1c used as light sources and coupling lenses 2a and 2b, and 2c that have a 1:1 correspondence relationship with respect to these semiconductor lasers. These semiconductor lasers 1a-1c and coupling lenses 2a-2c are determined to have a mutual positional relationship and are held together by holding means not shown. The semiconductor lasers 1a-1c and the coupling lenses 2a-2c are identical in structure with each other and are arranged roughly in the main scanning direction. Additionally, the coupling lenses 2a-2c convert divergent light beams from corresponding light

emitting parts of the semiconductor lasers 1a-1c into "substantially collimated beams." That is, each of the light-emitting parts of the semiconductor lasers is situated substantially on the focal plane of the corresponding coupling lens. Fig. 1(c) shows a state in which the coupling lenses 2a-2c are arranged in the main scanning direction. The sign "+" drawn at the center of each coupling lens shows the position of an optical axis. The optical axes of the coupling lenses 2a-2c are parallel to each other and are perpendicular to the drawing in Fig. 1(c). Reference characters Ha, Hb, and Hc designate the light emitting parts of the semiconductor lasers 1a and 1b, and 1c corresponding to the coupling lenses 2a and 2b, and 2c, respectively. The light emitting part Hb is situated on the optical axis of the coupling lens 2b. In contrast, the light emitting part Ha is deviated from the optical axis of the coupling lens 1a by "ζa" in the main scanning direction and by "ξa" in the sub-scanning direction. Likewise, the light emitting part Hc is deviated from the optical axis of the coupling lens 1c by "ζc" in the main scanning direction and by "ξc" in the sub-scanning direction. The positional relationship among the light emitting parts and the optical axes is set by use of a jig with high accuracy. Fig. 1(d) shows the motion of the principal ray of a light beam emitted from

each of the light emitting parts Ha, Hb, and Hc. Since the light emitting part Hb is situated (at a focal point) on the optical axis of the coupling lens 2b, the light beam emitted from the light emitting part Hb is changed into a collimated beam by the coupling lens 2b, and the principal ray travels while coinciding with the optical axis of the coupling lens 2b. In contrast, since the light emitting parts Ha and Hc are deviated from the optical axes of the corresponding coupling lenses 2a and 2c, these light beams emitted from the light emitting parts are changed into collimated beams by the corresponding coupling lenses, but, the direction of the principal ray is refracted by the coupling lenses as shown by the solid lines in the figure. Therefore, as a result, the directions of the principal rays of the light beams changed into collimated beams by the coupling lenses 2a and 2c have an inclination with respect to the optical axes of the coupling lenses 2a and 2c..

[0017] The three light beams emitted from the light source device 10 form light spots on the to-be-scanned surface and on the light receiving surface of the photosensor 24 in the same way as mentioned above. Fig. 1(e) shows a situation of the light spots on the light receiving surface of the photosensor 24 as an explanatory drawing. A situation of the light spots formed on the to-be-scanned surface is shown in

the same manner as this. In Fig. 1(e), the "light spots" shown by reference characters Sa, Sb, and Sc are the ones that are formed by the light beams emitted from the semiconductor lasers 1a and 1b, and 1c. These light spots Sa, Sb, and Sc are optically the images of the light emitting parts Ha, Hb, and Hc by the coupling lenses 2a and 2b, 2c, the cylindrical lens 12, and the fθ lens 16. The light spots are each shaped like an "ellipse" slightly long in the sub-scanning direction by adjusting the "magnitude of an opening" of a beam-reshaping aperture disposed at a proper position between the light source and the optical deflector. As shown in Fig. 1(e), centering on the light spot Sb, the light spot Sa is deviated by "δab" in the main scanning direction and by "ηab" in the sub-scanning direction, whereas the light spot Sc is deviated by "δbc" in the main scanning direction and by "ηbc" in the sub-scanning direction. Considering a "combining optical system" of the coupling lenses 2a-2c (which are optically equivalent, as mentioned above), the cylindrical lens 12, and the fθ lens 16, the combining optical system is an anamorphic optical system having a difference between the power in the main scanning direction and the power in the sub-scanning direction, and, when a lateral magnification of a formed image is represented as M (main) concerning the main scanning direction and as M (sub)

concerning the sub-scanning direction, δab, δbc, ηab, and ηbc mentioned above are given as follows:

$\delta ab = M(main) \cdot \zeta a$,

$\delta bc = M(main) \cdot \zeta c$

$\eta ab = M(sub) \cdot \xi a$, and

$\eta bc = M(sub) \cdot \xi c$

Since ηab and ηbc are each a scanning-line distance between two contiguous lines to be simultaneously scanned, the "deviation amount in the sub-scanning direction with respect to the coupling-lens optical axis" of the light emitting parts Ha and Hc is set so that "$\eta ab = \eta bc$," i.e., $|\xi a = \xi c|$.

[0018] On the other hand, concerning δab and δbc, light spots formed on the light receiving surface of the photosensor 24 by the deflected light beams are required to be individually detected by the photosensor 24, and therefore δab and δbc mentioned above must be greater than the resolution: Δ in the main scanning direction in the photosensor 24. In other words, since the light spots of the three deflected light beams can be individually detected by the same photosensor 24 when ζa and ζc mentioned above are determined to satisfy $\Delta \leq \delta ab$ and $\Delta \leq \delta bc$, the start positions of scanning by the deflected light beams can be independently controlled based on a detection result, and the start positions can be "arranged at the same position"

with high accuracy for each deflected light beam. So far as "$\Delta \leq \delta ab$ and $\Delta \leq \delta bc$" are satisfied, ζa and ζc may be set at $\xi a = \xi c$ or $\zeta a \neq \zeta c$. Since the combining optical system is an afocal system concerning the main scanning direction, the lateral magnification in the main scanning direction is given as M (main) = F/f wherein f is the focal length of the coupling lenses 2a-2c, and F is the focal length in the main scanning direction of the fθ lens 16. In the embodiment described above, although the deviation amount: ζb in the main scanning direction from the optical axis of the coupling lens 2b of the light emitting part Hb of the semiconductor laser 1b has been set at 0, ζb may be a finite value other than 0. It is recommended to set ζa, ζb, and ζc so that $\Delta \leq F/f|\zeta a - \zeta b|$ and $\Delta \leq F/f|\zeta c - \zeta b|$ can be established when $\zeta b \neq 0$. In this case, in Fig. 1(c), let ζa, ζb, and ζc be positive when situated on the right of the optical axis and be negative when situated on the left thereof.

[0019] The embodiment described above is a multi-beam scanning device for condensing a plurality of deflected light beams that are emitted from the light source device 10 and are deflected toward the to-be-scanned surface 20 through the scanning image formation optical system 16, for forming a plurality of light spots that are mutually separated in the sub-scanning direction on the to-be-scanned surface 20, and for scanning a plurality

of lines simultaneously by these light spots, in which the multi-beam scanning device has the synchronous light detecting means 22 and 24 for detecting the deflected light beam traveling to a scanning area of the to-be-scanned surface in order to synchronize the starting of scanning operations using the deflected light beams, and the light source device 10 that emits a plurality of light beams has at least N (=3) semiconductor lasers 1a-1c and at least N coupling lenses 2a-2c that have a 1:1 correspondence relationship with respect to each of the semiconductor lasers, the N coupling lenses 2a-2c being identical in structure with each other, the optical axes thereof being made parallel to each other with respect to the main scanning direction, the light beams from the corresponding semiconductor lasers being made substantially collimated beams, and, when two arbitrary deflected light beams contiguous to each other are represented as Bi and Bi+1(i=1 to N-1) in a light receiving surface position of the synchronous light detecting means and when deviation amounts in the main scanning direction from the optical axes of corresponding coupling lenses of semiconductor laser light-emitting parts that emit the beams Bi and Bi+1 are represented as ζi and $\zeta i+1$, the deviation amounts: ζi and $\zeta i+1$ are set to satisfy relation: $\Delta \leq M(\text{main}) \cdot |\zeta i - \zeta i+1|$ with respect to a lateral magnification:

M (main) in the main scanning direction of an optical system disposed between each semiconductor laser and the light receiving surface position and with respect to a resolution: Δ of the synchronous light detecting means, thereby making it possible to detect each of the deflected light beams individually by the synchronous light detecting means (Claim 1). Although the optical axes of the coupling lenses 2a-2c have been set to be parallel to each other in the aforementioned embodiment, it is permissible that these are made parallel to each other (i.e., mutually parallel when seen from the sub-scanning direction) only approximately the main scanning direction and that a slight angle is made between the optical axes approximately the sub-scanning direction. If so, light spots can be separated in the sub-scanning direction by adjusting the slight angle between the optical axes even if the aforementioned deviation amounts are set at $\xi a=\xi b=\xi c=0$.

[0020] Fig. 2 and Fig. 3 are views for explaining other forms of the embodiment of the light source device usable as a light source device of the multi-beam scanning device shown in Fig. 1(a). In order to avoid complexity, constituent elements that eliminate the fear of confusion employ the same reference characters, respectively, in all of the drawings including Fig 1. Fig. 2(a) is a view for explaining the structure of a main

part of this light source device. Reference characters 1a and 1b, 1c, and 1d designate semiconductor lasers, and reference characters 2a and 2b, 2c, and 2d designate "coupling lenses that have a 1:1 correspondence relationship to the semiconductor lasers 1a and 1b, 1c, and 1d." Reference characters 3A and 3B designate holding bodies, and reference character 4 designates a prism that serves as a beam combining means. The semiconductor lasers 1a and 1b, 1c, and 1d have the same structure, and, likewise, the coupling lenses 2a and 2b, 2c, and 2d have the same structure. Each of the coupling lenses is set to change a light beam emitted from a corresponding semiconductor laser into a collimated beam. Likewise, the holding bodies 3A and 3B have the same structure. The holding body 3A, the semiconductor lasers 1a and 1b, and the coupling lenses 2a and 2b constitute a "first light source part." The holding body 3B, the semiconductor lasers 1c and 1d, and the coupling lenses 2c and 2d constitute a "second light source part." Since the first and second light source parts have the "same structure," a description will be given taking the first light source part as an example. Fig. 2(b) is a view of the holding body 3A of the first light source part when seen from the front side. The drawing in which a C-C' section of this figure is drawn together with the semiconductor lasers and the

coupling lenses is Fig. 2 (c). As shown in (b) and (c) of Fig. 2, a base 300 of the holding body 3A is planar, and a convex portion 301 for holding a lens is formed at the middle thereof, and through-holes 302, 303 through which light passes are bored in both sides of the convex portion 301 in such a way as to sandwich the convex portion 301. The through-holes 302, 303 penetrate the base 300 in the thickness direction and are "parallel to each other." The hole diameters of the through-holes 302 and 303 are enlarged in the vicinity of a reverse-side exit of the base 300, and the semiconductor lasers 1a and 1b are pressed and fixed to the enlarged part thereof (Fig. 2(c)). Therefore, the positions of the light emitting parts of the semiconductor lasers 1a and 1b are univocally determined with respect to the through-holes 302 and 303.

[0021] The coupling lenses 2a and 2b are fixedly disposed at the convex portion 301 in such a way as to sandwich the convex portion and as to make the optical axes thereof parallel to each other. In (b) and (c) of Fig. 2, reference characters 304 and 305 designate threaded holes for fixation. Like the first light source part, the second light source part is formed by fixedly holding the semiconductor lasers 1c and 1d and the coupling lenses 2c and 2d (see Fig. 2(a)) into the holding body 3B. The first and second light source parts are disposed so

as to face the incident side surface of a prism 4 by making the optical axes of the coupling lenses parallel to each other. Referring to Fig. 3(a), this figure is a view for explaining the state of mounting the coupling lenses to the holding bodies, taking the state of mounting the coupling lens 2b to the holding body 3A as an example. As shown in the figure, the side face of the convex portion 301 is formed to have a concave, cylindrical face, and this cylindrical face serves as a reference plane to mount the coupling lens 2b. The coupling lens 2b has its edge part applied by an ultraviolet-cured resin 310, and the ultraviolet-cured resin 310 is brought into contact with the part of the cylindrical face. In the coupling lens 2b, a positional relationship (deviation amount in the main scanning direction: ζb and deviation amount in the sub-scanning direction: ξb) between the optical axis (represented as the sign "+") and the light emitting part Hb of the semiconductor laser 1b (which is a fixed position fixed by the holding body 3A) and a position in the optical-axis direction are adjusted by a jig (not shown). When the ultraviolet-cured resin 310 is irradiated with ultraviolet rays and is hardened in this positionally adjusted state, the coupling lens 2b is fixedly bonded to the convex portion 301. The other coupling lenses 2a, 2c, and 2d are "held into the

corresponding holding bodies" in the same way. Fig. 3(b) is a view for explaining a situation in which beams are combined by the prism 4, referring to light beams emitted from the light emitting parts Ha and Hc. The prism 4 has a side face shape as shown in Fig. 3(b). The prism 4 has a combined structure of a parallelogram prism and a right-angled prism, and a polarized-light reflective film 401 is formed at a junction of both the prisms. Additionally, a half-wave plate 403 is provided at a part (not shown, where a light beam emitted from the light emitting part Hd also is made incident) where a light beam emitted from the light emitting part Hc is made incident.

[0022] The positional state of the light source is determined so that any light emitted from the light emitting parts Ha and Hb becomes P-polarized light with respect to the polarized-light reflective film 401. Therefore, a light beam that is emitted from the light emitting part Ha and that is made into a collimated beam by the coupling lens 2a (in addition, a light beam, not shown, that is emitted from the light emitting part Hb and that is made into a collimated beam by the coupling lens 2b) is made incident on the prism 4, then passes through the polarized-light reflective film 401, and ejects from the prism 4. On the other hand, a light beam that is emitted from the light emitting part Hc and that is made into a collimated

beam by the coupling lens 2c (in addition, a light beam, not shown, that is emitted from the light emitting part Hd and that is made into a collimated beam by the coupling lens 2d) passes through the half-wave plate 403 and thereby becomes S-polarized light with respect to the polarized-light reflective film 401. The light beam then undergoes total reflection from a prism surface 402 of the prism 4, thereafter further undergoes total reflection from the polarized-light reflective film 401, and is made incident from the prism 4. The four light beams (any of which is a collimated beam) that are ejected from the prism 4 in this way are combined as light beams that are in close vicinity to each other. Two of the four light beams ejected from the prism 4 become S-polarized light, and the remaining two become P-polarized light, the polarization planes thereof being perpendicular to each other. As well known, the reflectance by a reflective surface exhibits different variations depending on whether the light is S-polarized light or P-polarized light as well as depending on a change in incident angle, and, if "the aforementioned state does not change at all," the light intensity of light spots on the to-be-scanned surface will exhibit different variations between the two light beams and the other two in response to a change in the reflectance when the four light beams emitted

from the light source device are reflected by the deflection reflective surface of the rotational polygon mirror 14, the return mirror 18, etc., shown in Fig. 1(a), and therefore, in order to avoid this problem, it is preferable to allow the four light beams subjected to a beam combination by the prism 4 to pass through a quarter-wave plate so that all four light beams reach a "circularly polarized light state." Fig. 3(c) shows a state in which the light source device 10 is seen obliquely from behind. The prism 4 is adjusted to reach a predetermined positional state and is contained in a box-like casing designated by reference numeral 5, and the holding body 3A that holds together the semiconductor lasers 1a and 1b and the coupling lenses 2a, and 2b (not shown) and the holding body 3B that holds together the semiconductor lasers 1c and 1d and the coupling lenses 2c, and 2d (not shown) are fixed to a rear side plate of the casing 5 by fitting a holding-body convex portion (to which the coupling lenses are fixed) into an engagement hole bored in the rear side plate and by adjusting a positional state. The four light beams (collimated beams) subjected to the beam combination are ejected from a cylindrical ejection exit 5A formed in the casing 5. The ejection exit 5A is provided with the "quarter-wave plate" and an aperture to reshape the beams. Therefore, any of the four

collimated light beams ejected from the light source device 10 is reshaped and is made into circularly polarized light.

[0023] The four light beams emitted from the light source device 10 form "line images long in the main scanning direction" that are mutually separated in the sub-scanning direction in the vicinity of the deflection reflective surface of the rotational polygon mirror 14 by the cylindrical lens 12 as shown in Fig. 1(a), are then made into deflected light beams by the rotational polygon mirror, and form light spots separated in the sub-scanning direction in accordance with the operation of the fθ lens 16 on the to-be-scanned surface that is a circumferential surface of the photo conductor 20. Thereafter, four lines (four scanning lines) on the to-be-scanned surface are simultaneously scanned by these four light spots. Fig. 4(a) shows the combining state of the prism 4 in the form of an explanatory drawing. Let it be assumed that the combination by the prism 4 is performed so that the center between the optical axes of the coupling lenses 2a and 2b and the center between the optical axes of the coupling lenses 2c and 2d coincide with each other at a position :q shown in the figure in the state of being seen from the combining side of the prism 4. In order to avoid making the figure complicated, the coupling lens 2a and the coupling lens 2c have been drawn so as to lie

on each other, and the coupling lens 2b and the coupling lens 2d have been drawn so as to lie on each other. Since the optical axes of the coupling lenses are parallel to each other and since the coupling operation causes the light beams from the semiconductor lasers to become collimated beams, no limitations are imposed on the position at which each of the coupling lenses is placed so far as the centers between the optical axes coincide with each other at the position: q. Therefore, the generality of a description given below is not lost even if the coupling lenses are drawn so that the two coupling lens lie on each other and so that the other two lie on each other as in Fig. 4(a). Let deviation amounts of the light emitting parts Ha and Hc of the semiconductor lasers 1a and 1c that are relative to the optical axes (represented as the sign "+") of the coupling lenses 2a and 2c be ζa and ζc concerning the main scanning direction and be ξa and ξc concerning the sub-scanning direction. Likewise, let deviation amounts of the light emitting parts Hb and Hd of the semiconductor lasers 1b and 1d that are relative to the optical axes (represented as the sign "+") of the coupling lenses 2b and 2d be ζb and ζd concerning the main scanning direction and be ξb and ξd concerning the sub-scanning direction. If relations are established as $3|\zeta a|=|\zeta c|$ and $3|\zeta b|=|\zeta d|$ and as

$3|\xi a|=|\xi c|$ and $3|\xi b|=|\xi d|$ at this time, the situation of the light spots Sa, Sb, Sc, and Sd formed on the to-be-scanned surface (in addition, on the light receiving surface of the photosensor 24) will be reached as shown in Fig. 4(b). "Q" designates an image at the aforementioned position: q formed by the cylindrical lens 12 and the fθ lens 16.

[0024] When the "distance in the main scanning direction" between adjoining light spots is represented as δab, δac, and δbd as shown in the figure, these can be expressed as follows, using the aforementioned image formation magnification: M(main)(=F/f).

$\delta ab=M(main)|\zeta b-\zeta a|$

$\delta ac=M(main)|\zeta c-\zeta a|$

$\delta bd=M(main)|\zeta d-\zeta b|$

If use is made of a resolution: Δ in the main scanning direction in the photosensor 24, what is needed to allow each of the light spots to be individually detected by the photosensor 24 is to satisfy the three conditions $\delta ab\leq\Delta$, $\delta ac\leq\Delta$, and $\delta bd\leq\Delta$ independently. In other words, what is needed is to set the deviation amounts: ζa, ζc, ζb, and ζd so that the aforementioned conditions can be satisfied in accordance with the aforementioned image formation magnification: M (main). The deviation amounts: ξa, ξb, ξc, and ξd in the sub-scanning

direction are set in accordance with the image formation magnification: M (sub) in the sub-scanning direction so that contiguous distances in the sub-scanning direction of the light spots Sa, Sb, Sc, and Sd coincide with predetermined scanning line pitches. Fig. 4(c) shows a case in which the positions of the light emitting parts Hb and Hd in Fig. 4(a) are replaced by each other. At this time, the light spots Sa, Sb, Sc, and Sd on the to-be-scanned surface are arranged as shown in Fig. 4(d). That is, the arrangement state of the light spots Sa, Sb, Sc, and Sd can be properly adjusted by adjusting the positional relationship among the light emitting parts and the coupling-lens optical axes. It will be easily understood from the description given above that conditions under which the light spots can be individually detected by the photosensor 24 are given as $\delta ad \leq \Delta$, $\delta ac \leq \Delta$, and $\delta bd \leq \Delta$ in the light-spot arrangement of Fig. 4(d).

[0025] The "light source device whose embodiment has been described in Fig. 2 to Fig. 4" and that has been used as the light source device 10 in the multi-beam scanning device shown in Fig. 1(A) is a multi-beam scanning device for condensing a plurality of deflected light beams that are emitted from the light source device 10 and are simultaneously deflected toward the to-be-scanned surface 20 through the scanning image

formation optical system 16, for forming a plurality of light spots that are mutually separated in the sub-scanning direction on the to-be-scanned surface, and for scanning a plurality of lines simultaneously by these light spots, the multi-beam scanning device characterized in that the multi-beam scanning device has synchronous light detecting means 22n and 24 for detecting the deflected light beam traveling to a scanning area of the to-be-scanned surface in order to synchronize the starting of scanning operations using the deflected light beams, and the light source device 10 that emits a plurality of light beams has a first light source part having n (=2) semiconductor lasers 1a and 1b, n coupling lenses 2a and 2b that have a 1:1 correspondence relationship with respect to each of the semiconductor lasers, and a holding body 3A that holds together the n semiconductor lasers and the n coupling lenses while making the optical axes of the n coupling lenses parallel to each other with respect to the main scanning direction so as to be maintained in a predetermined positional relationship, a second light source part having m (=2) semiconductor lasers 1c and 1d, m coupling lenses 2c and 2d that have a 1:1 correspondence relationship with respect to each of the semiconductor lasers, and a holding body 3B that holds together the m semiconductor lasers and the m coupling lenses while

making the optical axes of the m coupling lenses parallel to each other with respect to the main scanning direction so as to be maintained in a predetermined positional relationship, and beam combining means 4 for combining the n (=2) light beams emitted from the first light source part 3A and the m (=2) light beams emitted from the second light source part into light beams that are in close vicinity to each other, and a deviation amount: ζi (ζa, ζb) in the main scanning direction from the optical axis of a corresponding coupling lens of an arbitrary semiconductor laser light-emitting part in the first light source part, a deviation amount: ζk (ζc, ζd) in the main scanning direction from the optical axis of a corresponding coupling lens of an arbitrary semiconductor laser light-emitting part in the second light source part, and a positional relationship among the first and second light source parts and the beam combining means 4 are set so that deflected light beams contiguous to each other are separated in the main scanning direction by a distance exceeding a resolution: Δ of the synchronous light detecting means in a light receiving surface position of the synchronous light detecting means, thereby making it possible to detect each of the deflected light beams individually by the synchronous light detecting means (Claim 2).

[0026] The light source device that has been described with reference to Fig. 2 to Fig. 4 is characterized in that n=m and in that the first light source part and the second light source part have the same structure (Claim 3). Each of the semiconductor lasers in the first and second light source parts of the light source device is pressed and fixed into a corresponding holding hole of the holding body, and each of the coupling lenses is fixed to a corresponding holding body with an adhesive resin, and an optical-axis position with respect to a corresponding light-emitting part of the semiconductor laser is adjusted by the adhesive resin (Claim 4), and n=m=2 (Claim 5). Although the optical axes of the coupling lenses 2a-2d have been made parallel to each other in the embodiment described above, these optical axes may be made parallel "with respect to the main scanning direction" and may form a slight angle between each other with respect to the sub-scanning direction. If the optical axes of the coupling lenses form a slight angle with respect to the sub-scanning direction in this way, it is also possible to set the deviation amounts in the sub-scanning direction of the light emitting parts: ξa to ξd at "0." Additionally, it is easy to extend the embodiment described in Fig. 2 through Fig. 4 to a case in which the number: n, m of semiconductor lasers

and coupling lenses is set at 3 or more. In the embodiment referring to Fig. 1 through Fig. 4, the direction of deviations of the light emitting parts Ha and Hb with respect to the optical axes of the coupling lenses 2a and 2b has been described as, for example, a "direction in which they recede from each other," but the "direction of deviations" is not limited to this "direction in which they recede from each other." Taking the case of deviations of the light emitting parts Ha, Hb with respect to the optical axes of the coupling lenses 2a and 2b and describing this with reference to Fig. 5, the light emitting parts Ha and Hb may be deviated to approach each other in the main scanning direction as shown in Fig. 5(a). In this case, principal rays of the light beams changed into collimated beams by the coupling lenses 2a and 2b proceed in a direction in which they recede from each other in the main scanning direction. The light emitting parts Ha and Hb may be deviated in the "same direction" as shown in Fig. 5(b). In this case, the traveling direction of light beams that have been coupled can be determined so that the beams travel in a direction in which they intersect each other in the main scanning direction or so that the beams travel in a direction in which they recede from each other in the main scanning direction, in accordance with the large-and-small relationship between the deviation

amounts ζa and ζb in the main scanning direction.

[0027] Basically, in each embodiment described above, the relationship among the coupling optical axes is parallel to each other in the main scanning direction, and the light emitting parts of the semiconductor lasers are situated at positions where they deviate in the main scanning direction with respect to the optical axes of corresponding coupling lenses. In this case, a part of the light emitting parts will be disposed at "positions greatly apart" from the optical axes of the coupling lenses, proportionately with a rise in the number of deflected light beams used for simultaneous scanning. Since light beams from the thus disposed light emitting parts pass through the periphery of corresponding coupling lenses, the wavefront aberration in light beams coupled together becomes great. When the wavefront aberration reaches a certain level, this light beam enlarges the spot diameter of a light spot formed on the to-be-scanned surface. If an image is written with the thus formed light spot, the possibility that the image quality of the image that has been written and formed cannot realize an expected quality might exist. A possible countermeasure for avoiding this problem is to make the directions of the optical axes of the coupling lenses nonparallel to each other in the main scanning direction. Fig.

6 conceptually shows one example of the thus structured light source device. A main part of the light source device 10A has the semiconductor lasers 1a and 1b and the coupling lenses 2a and 2b that have a 1:1 correspondence relationship with respect to these. The figure shows a state when the light source device 10A is seen from the sub-scanning direction. As shown in the figure, the optical axes of the coupling lenses 2a and 2b are "nonparallel with respect to the main scanning direction." Both of the optical axes exist in the same plane with respect to the sub-scanning direction. If the light emitting parts of the semiconductor lasers 1a and 1b are represented as Ha and Hb and if deviation amounts from the optical axes of the coupling lenses 2a and 2b of the light emitting parts are represented as ζa and ζb concerning the main scanning direction and ξa and ξb concerning the sub-scanning direction as heretofore, the relation is established as $\zeta a = \zeta b = 0$, in which ξa and ξb are determined so that the light spots on the to-be-scanned surface are separated in the sub-scanning direction by a scanning line pitch. This makes it possible to effectively avoid the problem of a deterioration in the aforementioned wavefront aberration, without having a need to dispose the light emitting parts greatly apart from the optical axes of the coupling lenses (the same may be said of a case in which the semiconductor lasers

and the coupling lenses become great in number).

[0028] If the thus structured light source device is used as a light source device of the multi-beam scanning device shown in Fig. 1(a), conditions under which light spots can be individually detected on the light receiving surface of the photosensor 24 equivalent to the to-be-scanned surface will be described as follows. In Fig. 7, reference numeral 16 designates the "fθ lens 16 shown in Fig. 1(a)" that has been combined and unified. Considering a case in which a light beam having a convergent angle: φ in the main scanning direction (upward and downward directions in the figure) is made incident on the fθ lens 16 as shown in the figure, the incident light beam has a convergent angle "γφ" converted by the fθ lens 16 and forms an image at a P point in the figure. The beam is extended by "δ" in the main scanning direction on the to-be-scanned surface 20 apart from the image-forming point P by a distance: S. "γ" mentioned here is called an angular magnification in the main scanning direction of the fθ lens 16. The angular magnification: γ is univocally fixed in accordance with the fθ lens 16. Herein, let it be assumed that the convergent angle: φ in Fig. 7 is an "angle in the main scanning direction" between principal rays of two light beams emitted from the light source device 10A shown in Fig. 6. Then,

the principal rays of the two light beams intersect each other at the P point, but each light beam (deflected light beam) forms an image at the position of the to-be-scanned surface 20. Therefore, the two light spots formed on the to-be-scanned surface by image formation are separated by a distance: δ in the main scanning direction. The distance: δ can be expressed as $\delta=2\cdot\tan(\gamma\varphi/2)$ using the angle: $\gamma\varphi$ and the distance: S of Fig. 7. Therefore, a condition under which the two light spots can be individually detected is to establish $\Delta\leq\delta=2S\cdot\tan(\gamma\varphi/2)$ with respect to the resolution: Δ of the photosensor 24. The use aspect of the fθ lens 16 is fixed as a design condition, and the angular magnification: γ is also fixed as the characteristic of the fθ lens 16. If the angle: φ is fixed, the position of the P point and, accordingly, the distance: S are fixed. Therefore, what is needed is to set the angle: φ so as to satisfy the aforementioned condition "$\Delta\leq\delta=2S\cdot\tan(\gamma\varphi/2)$." The description given above can be easily extended also to a case in which the number of light beams is three or more.

[0029] That is, the light source device that emits a plurality of light beams has at least N ($\geq$3) semiconductor lasers and at least N coupling lenses that have a 1:1 correspondence relationship with respect to the semiconductor lasers, and the N coupling lenses are identical in structure with each other,

and, if the optical axes of the lenses are made nonparallel to each other in the main scanning direction, what is needed is to, when two arbitrary deflected light beams contiguous to each other are represented as Bi and Bi+1 (i=1 to N-1) in a light receiving surface position of the synchronous light detecting means, set an angle: φi in the main scanning direction between the optical axes of the coupling lenses corresponding to the semiconductor lasers that emit these beams Bi and Bi+1 so that a "distance in the main scanning direction between the beams Bi and Bi+1 exceeds a resolution: Δ of the synchronous light detecting means" (Claim 6). For example, if the number of light beams emitted from the light source device is four, if these beams are represented as B_1 to B_4, and if these beams are sequentially contiguous to each other at the light receiving surface position of the synchronous light detecting means, then the light source device should be structured so that the light beams B_1 and B_2 are made incident on the fθ lens while making an angle:φ12 in the main scanning direction, and, likewise, the light beams B_2 and B_3 are made incident on the fθ lens while making an angle:φ23 in the main scanning direction, and the light beams B_3 and B_4 are made incident on the fθ lens while making an angle:φ34 in the main scanning direction, and, when a distance from the position where the principal rays of the

light beams B_1 and B_2 intersect each other to the light receiving surface is represented as S_{12}, when a distance from the position where the principal rays of the light beams B_2 and B_3 intersect each other to the light receiving surface is represented as S_{23}, and when a distance from the position where the principal rays of the light beams B_3 and B_4 intersect each other to the light receiving surface is represented as S_{34},

$\Delta \leq 2S_{12} \cdot \tan(\gamma\varphi_{12}/2)$,

$\Delta \leq 2\ S_{23} \cdot \tan(\gamma\varphi_{23}/2)$, and

$\Delta \leq 2S_{34} \cdot \tan(\gamma\varphi_{34}/2)$

are satisfied with respect to the resolution: Δ of the synchronous light detecting means, thereby making it possible to individually detect the light spots. Δ If the light emitting parts of the semiconductor lasers have "no deviation ($\zeta=0$)" in the main scanning direction with respect to the optical axes of the corresponding coupling lenses, the angles in the main scanning direction between the optical axes of the coupling lenses should be set at the angles φ_{12}, φ_{23}, and φ_{34} mentioned above.

[0030] Fig. 8 shows a concrete example of the light source device shown in Fig. 6. Two through-holes 302', 303' are bored in a holding body designated by reference numeral 30 at an angle to each other in the thickness direction, and semiconductor

lasers 1a and 1b are pressed and fixed to the ends of the through-holes, respectively. Coupling lens 2a and 2b corresponding to the semiconductor lasers 1a and 1b are bonded and fixed to a convex portion that protrudes from the middle of the holding body 30 in the same way described with reference to Fig. 3. However, in this example, the position of each of the coupling lenses is adjusted so that light emitting parts of the semiconductor lasers are situated on the optical axes of the corresponding coupling lenses. The optical axes of the coupling lenses 2a and 2b are nonparallel to each other in the main scanning direction as shown in the figure, and light spots formed by the light beams make a slight angle to each other in the sub-scanning direction so that the light spots are separated in the sub-scanning direction on the to-be-scanned surface (instead of doing this, it is permissible that both of the optical axes are placed to be in the same plane parallel to the main scanning direction, and the light emitting parts of the semiconductor lasers corresponding to the coupling lenses are displaced from the aforementioned optical-axis position in the sub-scanning direction). Two light beams nonparallel to each other in the main scanning direction can be obtained in this way. The coupling lenses are optically the same and convert divergent light beams emitted from the light

emitting parts into collimated beams. Two optical devices, which have the same structure and which are shown in Fig. 8, can be used and structured as light source devices each of which is identical with the device described with reference to Fig. 2 together with the aforementioned prism 4 so as to serve as first and second light source parts, and two light beams from the first light source part and two light beams from the second light source part can be emitted in the form of four collimated light beams contiguous to each other by combining the beams together by the prism 4. Fig. 9 is a view for explaining the thus structured light source device. The device designated by reference character 3C in Fig. 9 is the light source shown in Fig. 8 and is the first light source part. Reference character 3D designates the second light source part having the same structure as the first light source part 3C. The first light source part 3C and the second light source part 3D are disposed apart from each other by "L" in the main scanning direction as shown in the figure, and light beams B_1 and B_3 emitted from the first light source part 3C and light beams B_2 and B_4 emitted from the second light source part 3D are combined so as to be alternately arranged in the main scanning direction (in order to do it in this manner, a "straight line that bisects an angle between the optical axes of the two coupling lenses" in each

light source part makes an angle to the other one in a plane parallel to the plane of Fig. 9 with the first light source part 3C and the second light source part 3D, not shown in Fig. 9). These four light beams are combined by a prism not shown (beam combining means, which is the same as the prism 4 shown in Fig. 2).

[0031] If these light beams B_1, B_2, B_3, and B_4 form light spots S_1, S_2, S_3, and S_4, respectively, which have the same arrangement as the arrangement of the beams, on the to-be-scanned surface (in addition, on the light receiving surface of the synchronous light detecting means) as shown in the right view of Fig. 9, the condition under which these light spots can be individually detected is that the angles: φ_{12}, φ_{23}, and φ_{34} made by the light beams shown in Fig. 9 in the main scanning direction satisfy the aforementioned condition:

$\Delta \leq 2S_{12} \cdot \tan(\gamma\varphi_{12}/2)$,

$\Delta \leq 2S_{23} \cdot \tan(\gamma\varphi_{23}/2)$, and

$\Delta \leq 2S_{34} \cdot \tan(\gamma\varphi_{34}/2)$

with respect to the angular magnification: γ of the $f\theta$ lens and with respect to the resolution: Δ of the synchronous light detecting means, and, by constructing the light source device in this way, the four light beams can be individually detected. The to-be-scanned surface that is the circumferential surface

of the photo conductor 20 can be scanned simultaneously with four-beam units by using the light source device described with reference to Fig. 9 as the light source device 10 of the multi-beam scanning device shown in Fig. 1(a). That is, the thus structured multi-beam scanning device is a multi-beam scanning device for condensing a plurality of deflected light beams that are emitted from the light source device 10 and are simultaneously deflected toward the to-be-scanned surface 20 through the scanning image formation optical system 16, for forming a plurality of light spots that are mutually separated in the sub-scanning direction on the to-be-scanned surface, and for scanning a plurality of lines simultaneously by these light spots, the multi-beam scanning device characterized in that the multi-beam scanning device has the synchronous light detecting means 22 and 24 for detecting the deflected light beam traveling to a scanning area of the to-be-scanned surface in order to synchronize the starting of scanning operations using the deflected light beams, and the light source device that emits a plurality of light beams has the first light source part 3C, the first light source part having n (=2) semiconductor lasers, n coupling lenses that have a 1:1 correspondence relationship with respect to the semiconductor lasers, and a holding body that holds together the n semiconductor lasers

and the n coupling lenses so that the optical axes of the n coupling lenses mutually make a predetermined angle in the main scanning direction while being maintained in a predetermined positional relationship, the second light source part 3D, the second light source part having m (=2) semiconductor lasers, m coupling lenses that have a 1:1 correspondence relationship with respect to each of the semiconductor lasers, and a holding body that holds together the m semiconductor lasers and the m coupling lenses so that the optical axes of the m coupling lenses mutually make a predetermined angle in the main scanning direction while being maintained in a predetermined positional relationship, and beam combining means for combining the n light beams emitted from the first light source part 3C and the m light beams emitted from the second light source part 3D into light beams in close vicinity to each other, and an optical-axis direction of each of the coupling lenses in the first and second light source parts and a mutual positional relationship among the first and second light source parts and the beam combining means are set so that deflected light beams contiguous to each other are mutually separated in the main scanning direction by a distance exceeding a resolution : Δ of the synchronous light detecting means, thereby making it possible to individually detect the deflected light beams by

the synchronous light detecting means (Claim 7).

[0032] Additionally, n=m, and the first light source part 3C and the second light source part 3D have the same structure (Claim 8), and a light emitting part of each semiconductor laser in the light source device is disposed on the optical axis of a corresponding coupling lens (Claim 9), and n=m=2 (Claim 10). Generally, in the light source device used in the invention as set forth in Claim 6 described above, at least P ($2 \leq P \leq N$) light emitting parts of the N (≥ 2) semiconductor lasers can be placed to deviate from the optical axis of a corresponding coupling lens in the main scanning direction (Claim 11). Likewise, in the light source device described with reference to Fig. 9, at least P ($2 \leq P \leq n+m$) light emitting parts of n+m semiconductor lasers can be placed to deviate from the optical axis of a corresponding coupling lens in the main scanning direction (Claim 12), and n=m even in this case, and the first light source part and the second light source part can be formed to have the same structure (Claim 13), and the relation n=m=2 can be established. The direction of a principal ray of a light beam changed into a collimated beam can be deviated from the optical-axis direction of the coupling lens in the main scanning direction by deviating the light emitting part of the semiconductor laser from the optical axis of a corresponding

coupling lens in the main scanning direction, and therefore angles (the aforementioned angles: φ23, etc.) between light beams in the main scanning direction can be easily adjusted. Moreover, in each light source device described above, it is preferable to allow all of the light beams emitted from the semiconductor laser to intersect each other in the main scanning direction in the vicinity of the deflection reflective surface of the rotational polygon mirror 14. A description thereof is given with reference to Fig. 10. In Fig. 10, the upward and downward direction is the main scanning direction. In Fig. 10(a), for example, light beams from the light emitting parts Ha and Hb are made incident on the deflection reflective surface 14A of the rotational polygon mirror while being mutually expanded. Considering a G point in the main scanning direction on the to-be-scanned surface 20 on the assumption that the rotative direction of the rotational polygon mirror is the direction of an arrow, the deflection reflective surface 14A is situated at the position of a solid line when a light spot of a light beam emitted from the light emitting part Ha is situated at the G point, and the light beam reaches the G point through an optical path shown by the solid line. On the other hand, at a time point where the light beam emitted from the light emitting part Hb forms a light spot at the G point,

the deflection reflective surface 14A is rotated up to the positional state of a broken line, and the light beam reaches the G point through the optical path shown by a broken line. As can be understood from this view, if light beams emitted from the light emitting parts Ha and Hb have their incident positions apart from each other on the deflection reflective surface 14, the two light beams pass through "considerably different optical paths" and pass through different positions of the fθ lens 16, and therefore the optical operations of the fθ lens 16 with respect to the light beams that form images at the G point do not become identical. For this reason, optical properties, such as aberrations, become different between two light beams that reach the same image height in the main scanning direction on the to-be-scanned surface 20, and there is a fear that a bend will arise and cause a variation between the image heights of a scanning line pitch.

[0033] In contrast to this, if the light beams from the light emitting parts Ha and Hb are set to intersect each other in the main scanning direction in the vicinity of the deflection reflective surface 14A as shown in Fig. 10(b), the light beams (deflected light beams) traveling to the same image height on the to-be-scanned surface 20 will pass through substantially the same optical path, and the problem of the aforementioned

scanning-line bend or the problem of the "variation between the image heights of the scanning line pitch" resulting from this will not arise. Additionally, the radius of an inscribed circle of the rotational polygon mirror 14 can be reduced, and the rotational polygon mirror can be rotated at high speed by forming all of the light beams emitted from the light source device so as to intersect each other in the main scanning direction in the vicinity of the deflection reflective surface, and therefore the advantage in increasing the speed of scanning is obtained. The multi-beam scanning device as set forth in Claim 15 is the multi-beam scanning device whose embodiment has been variously described, and the structure thereof is formed so that a plurality of light beams emitted from the light source device are simultaneously deflected by the same deflection reflective surface of an optical deflector, and the light source device is structured so that the plurality of light beams intersect in the vicinity of the deflection reflective surface in the main scanning direction. If the thus structured light source device used in the multi-beam scanning device is realized by, for example, the light source device shown in Fig. 9, the light beams B_1, B_2, B_3, and B_4 should be intersected with each other in the main scanning direction in the vicinity of the deflection reflective surface by adjusting the angles: φ12,

φ23, and φ34 shown in the figure. Additionally, a possible way to realize it by the light source device described with reference to Fig. 2 is to separate the holding bodies 3A and 3B (which have been simplified to be shown) in the main scanning direction (the upward and downward direction in the figure) by a distance: L, and to alternately arrange the light beams Ba and Bb emitted from the light emitting parts Ha and Hb and the light beams Bc, Bd emitted from the light emitting parts Hc and Hd in the main scanning direction, and to allow these to intersect each other in the vicinity of the deflection reflective surface 14A, as shown in Fig. 11. Fig. 11(b) shows one example of the positional relationship among the coupling lenses 2a and 2b, 2c and 2d and the relationship among the light emitting parts Ha, Hb, Hc and Hd. Since the same ones are used as the holding bodies 3A and 3B that hold the coupling lenses and the semiconductor lasers, the distance; Aab between the light emitting parts Ha and Hb and the distance Acd between the light emitting parts Hc and Hd are the same. The relative positional relationship between the light emitting parts and the optical axes of the corresponding coupling lenses is appropriately set when the coupling lenses are bonded and fixed.

[0034] In the example shown in Fig. 11(b), the holding body

3B that holds the coupling lenses 2c and 2d is inclined lengthways with respect to the holding body 3A that holds the coupling lenses 2a and 2b. Fig. 11(c) shows a state in which the arrangements of the light emission parts shown in Fig. 11(b) are combined by the prism 4 (see Fig. 2) that is a beam combining means. Reference numeral 2 designates a combined virtual coupling lens. Fig. 11(d) shows the situation of four light spots Sa, Sb, Sc, and Sd formed on the to-be-scanned surface (in addition, on the light receiving surface of the synchronous light detecting means) by light beams emitted from the light emitting parts Ha, Hb, Hc, and Hd at this time. The multi-beam scanning device of Fig. 1(a) using each light source device described above as the light source device 10 is characterized in that the structure is formed so that a plurality of light beams emitted from the light source device 10 are simultaneously deflected by the same deflection reflective surface of the optical deflector 14, and in that there is provided the line image formation optical system 12 that forms the plurality of light beams emitted from the light source device between the light source device 10 and the optical deflector 14 as line images long in the main scanning direction that are mutually separated in the sub-scanning direction in the vicinity of the deflection reflective surface, and in that

the scanning image formation optical system 16 is anamorphic so as to establish a geometrical-optical conjugate relationship in the sub-scanning direction between the deflection reflective surface position and the to-be-scanned surface position (Claim 16). The light source device variously described above is a light source device used for a multi-beam scanning device and has the structure set forth in any one of Claims 1 to 16 (Claim 17). As the embodiment has been described above, the use of the multi-beam scanning device makes it possible to realize a multi-beam scanning method for condensing a plurality of deflected light beams that are emitted from a light source device and are deflected toward a to-be-scanned surface through a scanning image formation optical system, and for forming a plurality of light spots that are mutually separated in the sub-scanning direction on the to-be-scanned surface, and for scanning a plurality of lines simultaneously by these light spots (Claims 18 and 19).

[0035]

[Example] A concrete example of the embodiment described with reference to Fig. 1 is mentioned as one concrete embodiment. The focal length f of each coupling lens in the light source device 10 is 27mm, and the focal length F in the main scanning direction of the f θ lens 16 is 225.3mm. Therefore, the

aforementioned image formation magnification M (main) (=F/f) is 8.34. The condition under which the light spots Sa, Sb, and Sc shown in Fig. 1(e) can be individually detected at this time is that $\Delta \leq \delta ab = M(main) \cdot \zeta a$ and $\Delta \leq \delta bc = M(main) \cdot \zeta c$ by use of δab and δbc of the figure on the assumption that the resolution Δ of the photosensor 24 is 0.5mm as mentioned above. Considering that M (main) is 8.34, deviation amounts: ζa, ζc in the main scanning direction of the light emitting parts Ha and Hc relative to the optical axes of the coupling lenses should be $\zeta a = \zeta c \geq 0.06$mm(=0.5/8.34) respectively.

[0036] Fig. 12 shows one embodiment of the image forming apparatus of this invention. A photoconductive photo conductor 20 serving as a latent image carrier is shaped like a cylinder, is rotated in the direction of an arrow at uniform speed, is uniformly electrified by an electrification means (a corona discharge type may be used although a contact type by an electrification roller is shown) 112, and has an electrostatic latent image formed by the writing through optical scanning of the multi-beam scanning device 114. This electrostatic latent image is developed by a developing means 116, and a toner image obtained by the development is transferred onto a sheet-like recording medium (transfer paper, a plastic sheet for an overhead projector, etc.) S by a transfer means (a roller

type may be used although a transfer/separation type is shown) 120. The recording medium S has the transferred toner image fixed by a fixing means 122 and is discharged outside the device. The photo conductor 20 to which the toner image has been transferred undergoes a removal step to remove residual toners, paper dust, etc., by a cleaning device 124. The one as set forth in any one of Claims 1 to 16 whose embodiment has been described above is used as the multi-beam scanning device 114. That is, the image forming apparatus shown in Fig. 12 is an image forming apparatus for forming a latent image on the latent image carrier 20 by optical scanning and obtaining a desired recorded image by visualizing the latent image, and the image forming apparatus uses the multi-beam scanning device as set forth in Claims 1 to 15 or in Claim 16 as an optical scanning device that subjects the latent image carrier to optical scanning (Claims 20 and 21), and the latent image carrier 20 is a photoconductive photo conductor, and an electrostatic latent image is formed by uniform electrification thereof and by optical scanning, and a formed electrostatic latent image is visualized as a toner image (Claim 22).

[0037]

[Effects of the Invention] As described above, according to this invention, it is possible to realize a new multi-beam

scanning device, a new multi-beam scanning method, a new light source device, and a new image forming apparatus. In the multi-beam scanning device and the multi-beam scanning method of this invention, since a plurality of deflected light beams traveling to a scanning area can be individually detected by the synchronous light detecting means in order to simultaneously scan the to-be-scanned surface, the timing of the start of scanning can be independently set for each deflected light beam, and, since the writing start positions of images to be written can be arranged with respect to all deflected light beams by simultaneous scanning, extremely excellent image writing can be realized. Additionally, since the light source device of this invention separates a plurality of deflected light beams to be simultaneously scanned in the main scanning direction so that the beams can be individually detected on the way to the scanning area, the aforementioned excellent image writing can be carried out. Additionally, since the image forming apparatus of this invention performs image writing by use of the aforementioned multi-beam scanning device, images can be excellently formed at high speed and. Additionally, constituent parts can be shared by forming the first and second light source parts used in the light source device so as to have the same structure as in the multi-beam

scanning device as set forth in Claims 3 through 5, 8, and 10, and the light source device can be reduced in cost.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1] View for explaining one embodiment of the multi-beam scanning device of this invention.

[Fig. 2] View for explaining one embodiment of the light source device of this invention.

[Fig. 3] View for explaining the optical apparatus of the embodiment of Fig. 2.

[Fig. 4] View for explaining one example of a state in which light spots are formed when the light source device shown in Fig. 2 and Fig. 3 is used.

[Fig. 5] View for explaining another example of the positional relationship between the light emitting parts and the coupling lenses in the light source device shown in Fig. 2 and Fig. 3.

[Fig. 6] View for explaining an embodiment of the light source device in the invention as set forth in Claim 6.

[Fig. 7] View for explaining the condition under which light beams are individually detected in the invention as set forth in Claim 6.

[Fig. 8] View for explaining one concrete example of the light source device of the invention as set forth in Claim 6.

[Fig. 9] View for explaining one example of the light source

device in which two light source devices each of which is shown in Fig. 8 are combined and in which beams are combined by the prism that is a beam combining means.

[Fig. 10] View for explaining the advantage of the invention as set forth in Claim 15.

[Fig. 11] View for explaining one example of the light source device in the multi-beam scanning device as set forth in Claim 15.

[Fig. 12] View for explaining one embodiment of the image forming apparatus.

[Description of Symbols]

1a、1b、1c Semiconductor laser

2a、2b、2c Coupling lens

10 Light source device

12 Cylindrical lens (line image formation optical system)

14 Rotational polygon mirror (optical deflector)

16 Fθ lens (scanning image formation optical system)

20 Photo conductor (which forms the substance of the to-be-scanned surface)

22 Plane mirror

24 Photosensor

Fig.1

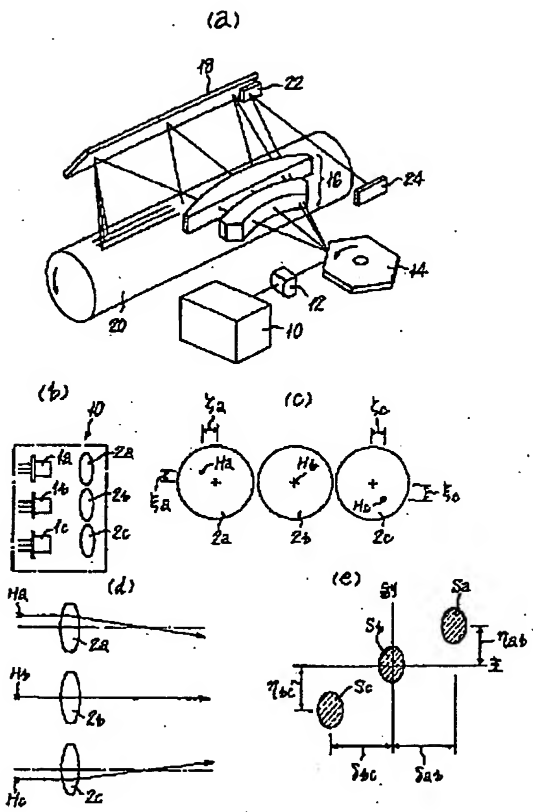

Fig.2

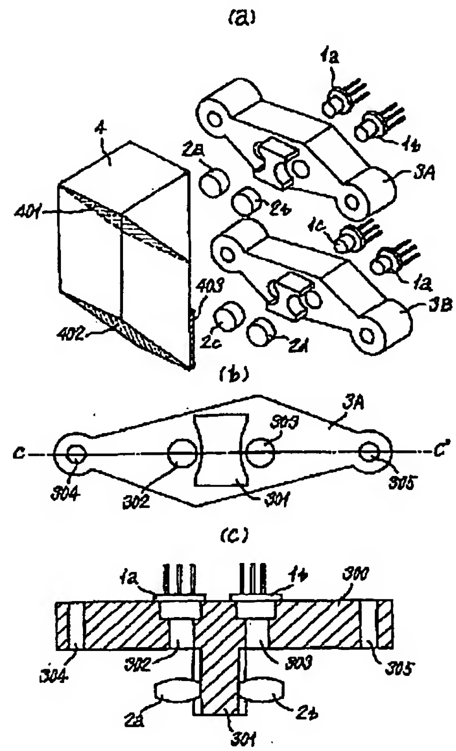

Fig.7

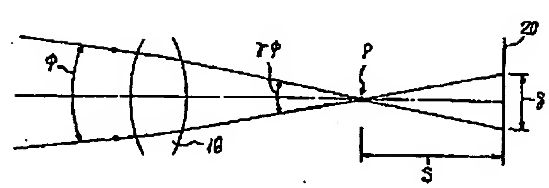

Fig.3

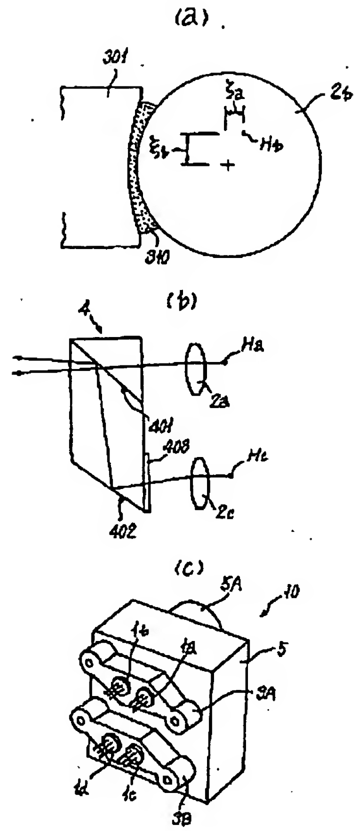

Fig.4

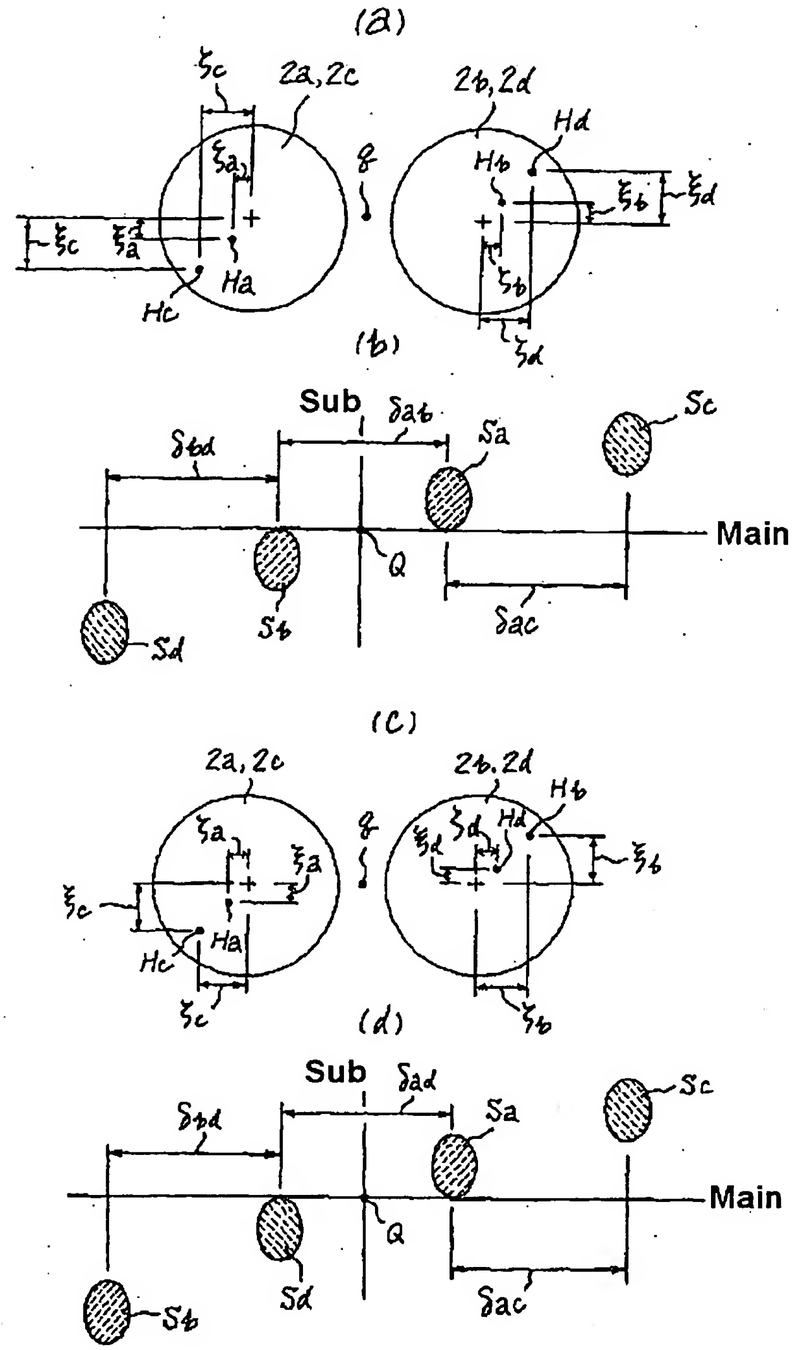

Fig.6

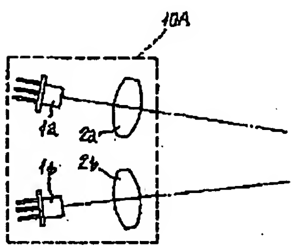

Fig.8

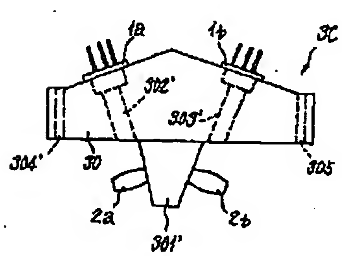

Fig.5

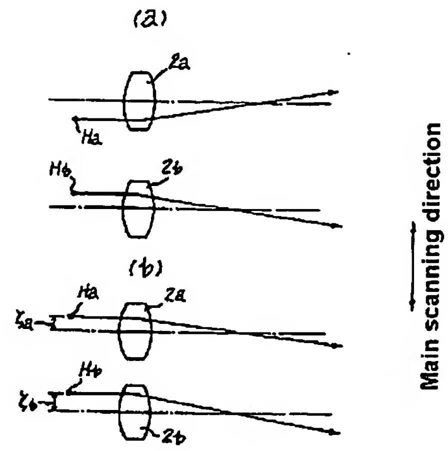

Fig.9

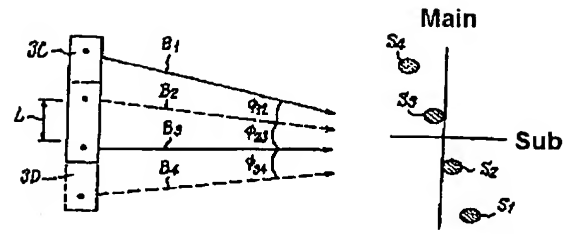

Fig.10

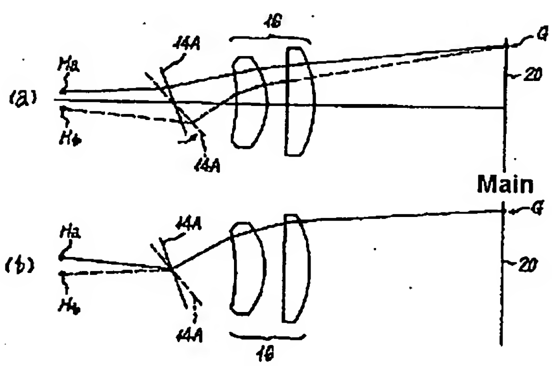

Fig.11

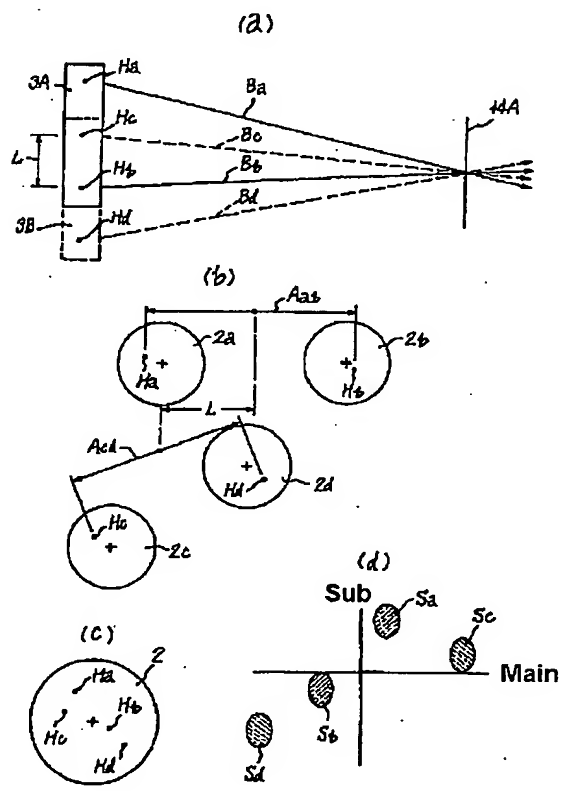

Fig.12